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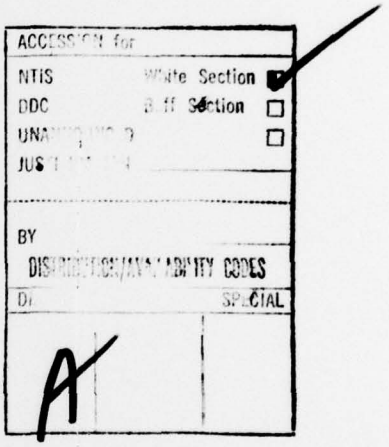

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Laminated and fiber-reinforced composites
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In this project attention has been focused on: (1) The accurate calculation of the dispersive properties of laminated and two- and three-dimensional fiber-reinforced elastic composites; (2) The accurate determination of natural frequencies of composite plates and beams, or plates and beams with variable dimensions or with inclusions; (3) Calculation of upper and lower bounds for the eigenfrequencies in (1) and (2); and (4) The assessment of the effect of fiber geometry on the dynamic properties of the fiber-reinforced composite.

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A. Statement of Problem Studied and Summary of Basic Results

In addition to their strength and special thermomechanical attributes, elastic composites, if properly designed, can be highly dispersive when subjected to stress pulses. Therefore, in using composites, one of the most significant objectives often is to implement a design which provides for a maximum attenuation by dispersion of stress waves without a sacrifice in the needed strength and other properties. Also, one needs to know the detailed stress distribution in a given composite when subjected to elastic waves. Furthermore, plates and shells with inclusions, with variable thicknesses, and/or with various reinforcements, are common ingredients of modern structural components in technology. The dynamic behavior and the thermal conductivity properties of these elements are of obvious importance to a designer.

Many characteristics of composites relating to the phenomenon of elastic wave propagation can be brought into focus by considering harmonic waves. For example, if the dispersion curve of a given composite deviates sharply from the straight line, the composite would be highly dispersive. Moreover, since pulses can be decomposed into their Fourier components, the dominant effect may be discussed in terms of the corresponding harmonics. Since these harmonics constitute the eigenfunctions, they can be suitably combined to define the response to various short-duration pulses. Thus it appears that the study of harmonic waves in composites can provide a basis for a better understanding and design of elastic composite materials. In a similar sense, many aspects of the dynamics of composite plates and shells can be understood in terms of their natural modes of vibration. In this project attention has been focused on: (1) The accurate calculation of the dispersive properties of laminated and two- and three-dimensional fiber-reinforced elastic composites; (2) The accurate determination of natural frequencies of composite plates and beams, or plates and beams with variable dimensions or with inclusions; (3) Calculation of upper and lower bounds for the eigenfrequencies in (1) and (2); and (4) The assessment of the effect of fiber geometry on the dynamic properties of the fiber-reinforced composite. This latter consideration can play an important role in the design of structural elements, such as helicopter blades, where it may become necessary, for example, to alter the vibrational frequencies of an element without having to modify its over-all geometry.

The calculations are based on a new quotient which has been formulated by the author recently. This quotient is based on a general variational method in which the displacement and stress fields are given independent variation. It has been shown under the present project that the new quotient yields extremely accurate results, even with the crudest approximating functions, hence making the new quotient superior to the Rayleigh quotient. With the aid of the new quotient, lower and upper bounds for the eigenfrequencies have also been obtained. These bounds are very close to each other.

B. List of Publications

S. Nemat-Nasser and F. C. L. Fu, "Improvable Lower and Upper Bounds for Frequencies of Harmonic Waves in Elastic Composites," Danish Center for Applied Mathematics and Mechanics (DCAMM) Report No. 42, Department of Solid Mechanics, Technical University of Denmark, April 1973.

F. C. L. Fu and S. Nemat-Nasser, "New Quotients and Their Lower and Upper Bounds for Frequencies of Harmonic Waves in Elastic Composites," Proceedings Fourth Canadian Congress of Applied Mechanics, Montreal, Canada (1973) 485-486.

S. Nemat-Nasser, "General Variational Principles in Nonlinear and Linear Elasticity with Applications," Mechanics Today, Vol. 1, edited by S. Nemat-Nasser, Pergamon Press, New York (1974) 214-261.

S. Nemat-Nasser and F. C. L. Fu, "Harmonic Waves in Layered Composites: Bounds on Frequencies," Journal of Applied Mechanics, Vol. 41 (1974) 288-290.

S. Nemat-Nasser, F. C. L. Fu, and S. Minagawa, "Harmonic Waves in One-, Two-, and Three-Dimensional Composites: Bounds for Eigenfrequencies," International Journal of Solids and Structures, Vol. 11 (1975) 617-642.

S. Nemat-Nasser and S. Minagawa, "Harmonic Waves in Layered Composites: Comparison Among Several Schemes," Journal of Applied Mechanics, Vol. 42 (1975) 699-704.

S. Minagawa and S. Nemat-Nasser, "Harmonic Waves in Three-Dimensional Elastic Composites," International Journal of Solids and Structures, Vol. 12 (1976) 769-777.

K.-W. Lang and S. Nemat-Nasser, "Vibration and Buckling of Composite Beams," Journal of Structural Mechanics, Vol. 5(4)(1977) 395-419.

S. Minagawa and S. Nemat-Nasser, "On Harmonic Waves in Layered Composites," Journal of Applied Mechanics, Vol. 44 (1977) 689-695.

S. Nemat-Nasser and K.-W. Lang, "Eigenvalue Problems for Heat Conduction in Composite Materials," Iranian Journal of Science and Technology, in press.

C. O. Horgan, K.-W. Lang, and S. Nemat-Nasser, "Harmonic Waves in Layered Composites: New Bounds on Eigenfrequencies," Journal of Applied Mechanics, in press.

C. O. Horgan and S. Nemat-Nasser, "Bounds on Eigenvalues of Sturm-Liouville Systems with Discontinuous Coefficients," Zeitschrift für angewandte Mathematik und Physik (ZAMP), in press.

K.-W. Lang and S. Nemat-Nasser, "Vibration and Stability of Rectangular Strip-Plates," Journal of Sound and Vibration, in press.

S. Nemat-Nasser and C. O. Horgan, "Variational Methods for Eigenvalue Problems with Discontinuous Coefficients," Mechanics Today, Vol. 5 (Proceedings of Symposium Honoring Prof. E. Reissner on his 65th Birthday), edited by S. Nemat-Nasser, Pergamon Press; to appear.

C. O. Horgan and S. Nemat-Nasser, "Variational Methods for Eigenvalue Problems in Composites," Proceedings of IUTAM Symposium on Variational Methods in the Mechanics of Solids, edited by S. Nemat-Nasser, Pergamon Press; to appear.

K.-W. Lang and S. Nemat-Nasser, "An Approach for Estimating Vibration Characteristics of Nonuniform Rotor Blades," in preparation.

Kuo-Wei Lang, "Determination of Dynamic Characteristics of Elastic Composite Structures," Ph.D. Dissertation, Northwestern University, August 1978.

C. List of Participants

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Short-Time Participation:

Professor T. Mura, consultation

Dr. K. S. Parihar, computer programing

Mr. C.-C. Mo (graduate student), computer programing